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(54) Blanket-medium/brine interface detection in a solution-mining process.

(55) A downhole tool, to be used in a solution-mining process for detecting capacitively the position of a blanket-medium/brine interface in salt cavities, said tool being provided with a first means which is placed at a determined distance from another means, both means being adapted for capacitive measurements, the first means consisting of a plurality of individual segments, arranged one above another, and further comprising means for determining the capacitance of the said two means, the said tool further being provided with means adapted to transmit the obtained information up-hole, wherein each individual segment of the first means has a height between 5 and 50 cm and a width between 1 and 5 cm.

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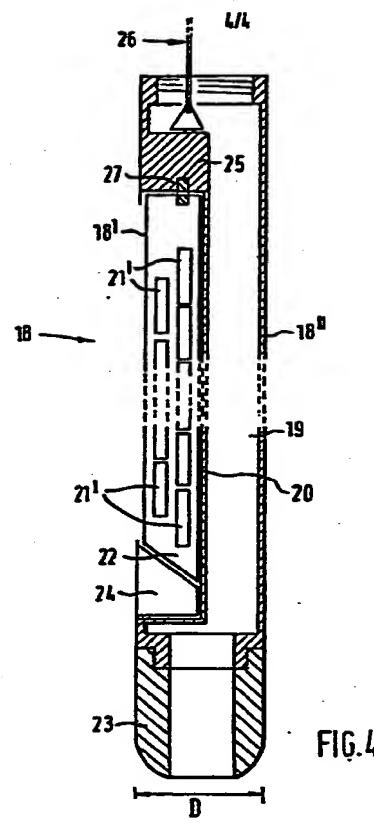


FIG. 4

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BLANKET-MEDIUM/BRINE INTERFACE DETECTION  
IN A SOLUTION-MINING PROCESS

The invention relates to a downhole tool to be used in a solution-mining process, in order to detect the position of a blanket-medium/brine interface in salt cavities.

5 In a solution-mining process subterranean salt layers which are situated at a relatively large depth, for example 1500-2000 metres, are mined by injecting a suitable medium such as fresh water into the layers and pumping out saturated brine through separate tubings. The salt layers have for example a thickness of about 100 metres.

10 The saturated brine is processed further in any way suitable for the purpose in order to obtain the desired products. Usually the fresh water injection point is above the brine off-take point. However, reverse flow is also possible. It will be clear that, when fresh water is injected into the salt layers, a subterranean 15 structure having a determined shape and comprising brine will be developed in these salt layers.

It is now desirable to protect the roof of such a structure by a "blanket medium" to prevent uncontrolled dissolution. An example of such a "blanket medium" is oil, but it will be clear to 20 those skilled in the art that any suitable medium, for example gas, can be used to protect the roof of the structure.

Further, as the radial extent of the mined section increases, the roof-surface area becomes larger, so that additional oil must be injected to maintain a sufficiently thick protecting layer 25 between roof and brine.

This can be achieved by keeping the oil-brine interface at a fixed level. Insufficient thickness of the blanket will result in local exposure of the roof to the brine, which in turn will cause more oil to disappear. Another cause of movement of the oil-brine 30 interface could be local roof failure. Part of the roof may collapse, creating a "chimney", into which the oil can disappear

leaving the remaining part of the roof unprotected. Hence, a safe mining process requires a continuous monitoring of the interface position and it will be clear that it is very important to have a good indication of the said position.

5 It is therefore an object of the invention to provide a down-hole tool to be used in a solution-mining process, which can detect accurately the interface position between oil-brine.

10 It is another object of the invention to provide a downhole tool to be used in a solution mining process which can be used to estimate the roof area at various stages of the mining process by measuring the change of the interface level when a known volume of oil is injected.

15 The invention therefore provides a downhole tool, to be used in a solution mining process for detecting capacitively the position of a blanket-medium/brine interface in salt cavities, said tool being characterized by a first means which is placed at a determined distance from another means, both means being adapted for capacitive measurements, the first means consisting of a plurality of individual segments, arranged one above another, and  
20 further comprising means for determining the capacitance of the said two means, the said tool further being provided with means adapted to transmit the obtained information up-hole, wherein each individual segment of the first means has a height between 5 and 50 cm and a width between 1 and 5 cm.

25 In an advantageous embodiment of the invention the said second means consists of a plurality of individual segments, arranged one above another wherein each individual segment has a height between 5 and 50 cm and a width between 1 and 5 cm.

30 In another advantageous embodiment of the invention the said first means consists of a plurality of individual segments of the above mentioned size, whereas the said second means consists of the wall of a tubing on which the tool is installed.

In this way it is possible to measure the interface position with an accuracy better than  $\pm 1$  cm.

Another advantage of the downhole tool of the invention is that it allows calibration of the level measuring system during the actual measurement by observing the capacitance of segments fully immersed in the brine and oil.

5 A further advantage of the tool of the invention is that it allows compensation of homogenous fouling of the measuring section.

The downhole tool of the invention will now be described by way of example in more detail with reference to the accompanying drawings, in which:

10 fig. 1 represents schematically a development of successive subterranean structures, obtained by a solution-mining process;

fig. 2 represents schematically a subterranean structure, in which the blanket-medium/brine interface level has changed due to local roof failure;

15 fig. 3a and fig. 3b represent schematically advantageous embodiments of the invention;

fig. 4 shows a longitudinal cross-section of an advantageous embodiment of the invention.

The downhole tool of the invention has been based upon the 20 capacitive measuring principle, in which the difference in capacitances for blanket medium and for cavity medium (brine) is used in order to determine the interface position. The capacitive measuring principle as such is known to those skilled in the art and will not be described in detail.

25 With reference now to fig. 1, a borehole 1 has been shown together with an injection tubing 2 and a production tubing 3. The reference numbers 2a-d represent successive positions of the injection tubing 2.

In the first position 2a of the injection tubing 2 a suitable 30 medium, such as fresh water, is injected into the salt layer A; brine 4 is developed in this layer and is pumped out through the production tubing 3 in any suitable way.

When, as shown, the fresh water is injected above the off-take point, a so-called "morning glory" structure A' results.

As already indicated in the above, the roof of the structure is protected by a blanket medium, such as oil. After the "morning glory" structure A' has reached a determined diameter, for example about 100 metres, the oil level is moved upwards over, for 5 example, 2 metres by producing back the oil to make a new "cut". At the same time the injection point is taken upwards by the same distance. In this way successive "morning glory" structures B', C', D' can be developed.

In fig. 1 the roof of the upper structure D' is protected by 10 oil 5', which is injected through the borehole 1 in any way suitable for the purpose and provides a protective oil layer 5.

Fig. 2 shows schematically a cavern 6 in the salt layer A, in which a change in blanket-medium/brine interface level has occurred due to local roof failure. A "chimney" 7 has developed 15 and comprises oil 5", so that part of the roof 8 is unprotected. The reference numbers 1, 2, 3, 4 and 5' are the same as used in fig. 1.

Fig. 3a shows schematically an advantageous embodiment of the downhole tool of the invention; in this embodiment of the tool 20 both the first means and the second means of the measuring section of the tool comprise a plurality of individual segments, thus forming capacitors 1', 1" - 13', 13", which are situated one above another. Each individual segment has a height between 5 and 50 cm and a width 1 and 5 cm. As will be explained afterwards, in 25 particular with reference to fig. 4, the downhole tool can be installed in any way suitable for the purpose. The individual capacitors 1', 1" - 13', 13", are connected in any way suitable for the purpose to any suitable downhole electronics, schematically shown as block 14, in order to measure the capacitances between 30 the segments of a capacitor.

The downhole electronics may, for example, consist of oscillators and a multiplexer (not shown). Such components and the operation thereof are known as such to those skilled in the art and will not be described in detail.

The block 14 is connected in any way suitable for the purpose to the earth surface 15 (not shown) in order to transmit the measured capacitances to suitable devices for processing further the obtained data (not shown for reasons of clarity).

5 In an advantageous embodiment of the invention a temperature sensor 17 and/or a pressure sensor 16 may be provided at any suitable position on the downhole tool in order to obtain information concerning the temperature and pressure in the cavern. Geothermal temperatures at the cavern depth are about 60°C. The 10 temperature of the injection fluids can vary between 10°C and 60°C. Practice has so far shown that the cavern temperature during production remains at about 60°C, even when water of 10°C is injected. However, injection of hot water up to 120°C may be considered. Thus, it will be clear that any downhole electronics 15 should be able to operate at temperatures up to 120°C. The operating pressure in the cavern is up to some 500 bar.

Fig. 3b represents schematically another advantageous embodiment of the downhole tool of the invention; in this embodiment of the tool the first means consists of individual 20 segments 1'a, 2'a....13'a, which are placed one below another. In this embodiment the segments are overlapping. The second means consisting of an electrode Z (schematically shown). The said first means and the said second means are connected by any means suitable for the purpose to a block 14a.

25 The block 14a has the same function as in fig. 3a, and has been connected to the earth surface by any means suitable for the purpose (schematically shown as 15a). Further a pressure sensor 16a and a temperature sensor 17a have been represented.

Fig. 4 shows a longitudinal section of an other advantageous 30 embodiment of the invention. In this embodiment the downhole tool of the invention is installed on an injection tubing 18". The way of installing such an injection tubing inside a borehole is known to those skilled in the art and will not be described in detail. The downhole tool 18 is provided with a measuring section 18'. The 35 measuring section 18' may, for example, have a length of about 2

metres. However, it will be appreciated that any length suitable for the purpose is possible. In this embodiment the reference number 19 represents the flow path of the injected water through the injection tubing 18".

5       The injection tubing is provided with a recessed part 20, made for example of stainless steel. The measuring section 18' is provided with a plurality of segments 21', arranged one above another, for example in an overlapping range. The diameter D of the tubing is for example 6.5 cm. However, it will be appreciated that any tubing-diameter suitable for the purpose can be used.

10      The said segments have, for example, a height of 20 cm and a width of 2 cm. The number of the segments is 13 in an advantageous embodiment, but any suitable number can be applied.

15      Further, suitable downhole electronics have been installed in the measuring section 18' (not shown in detail for reasons of clarity). The downhole electronics and segments are built into a suitable medium 22, for example an epoxy-glass reinforced module.

20      The tubing 20 may be provided with a protecting end section 23. The mechanical connections of the end section and the injection tubing will be clear to those skilled in the art and will not be described in detail.

25      Further, a retaining block 24 may be present at a first side of the module 22 in order to retain the said module. The retaining block 24 may for example be bolted onto the tubing 20. A support 25 may be present at the other side of the module 22 and is adapted to attach a cable 26 to the measuring section 18'.

30      A suitable cable feedthrough 27 from the measuring section 18' to the module 22 is present. The whole system can be run on a cable, for example a mono-conductor cable 26, which remains connected during operation to provide the electrical communication to the surface.

In the embodiment of fig. 4 the capacitance between the segments and the tubing wall is measured.

35      It will be appreciated that the segments 21' may have any shape suitable for the purpose and are not necessarily flat.



European Patent  
Office

**EUROPEAN SEARCH REPORT**

0111353  
Application number

EP 83 20 1618

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Y	US-A-2 688 872 (HARTLINE) * Whole document *	1,2	E 21 B 47/04 E 21 B 43/28 G 01 F 23/26
Y	GB-A- 578 886 (WAYMOUTH) * Whole document *	1,2	
A	DE-A-2 555 720 (BERTHOLD)		
A	FR-A-2 205 996 (RAYMOND et al.)		
A	US-A-2 409 674 (GRAYBEAL)		
	-----		TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
	-----		E 21 B G 01 F
<p>The present search report has been drawn up for all claims</p>			
Place of search <b>THE HAGUE</b>	Date of completion of the search <b>21-08-1985</b>	Examiner <b>BENZE W.E.</b>	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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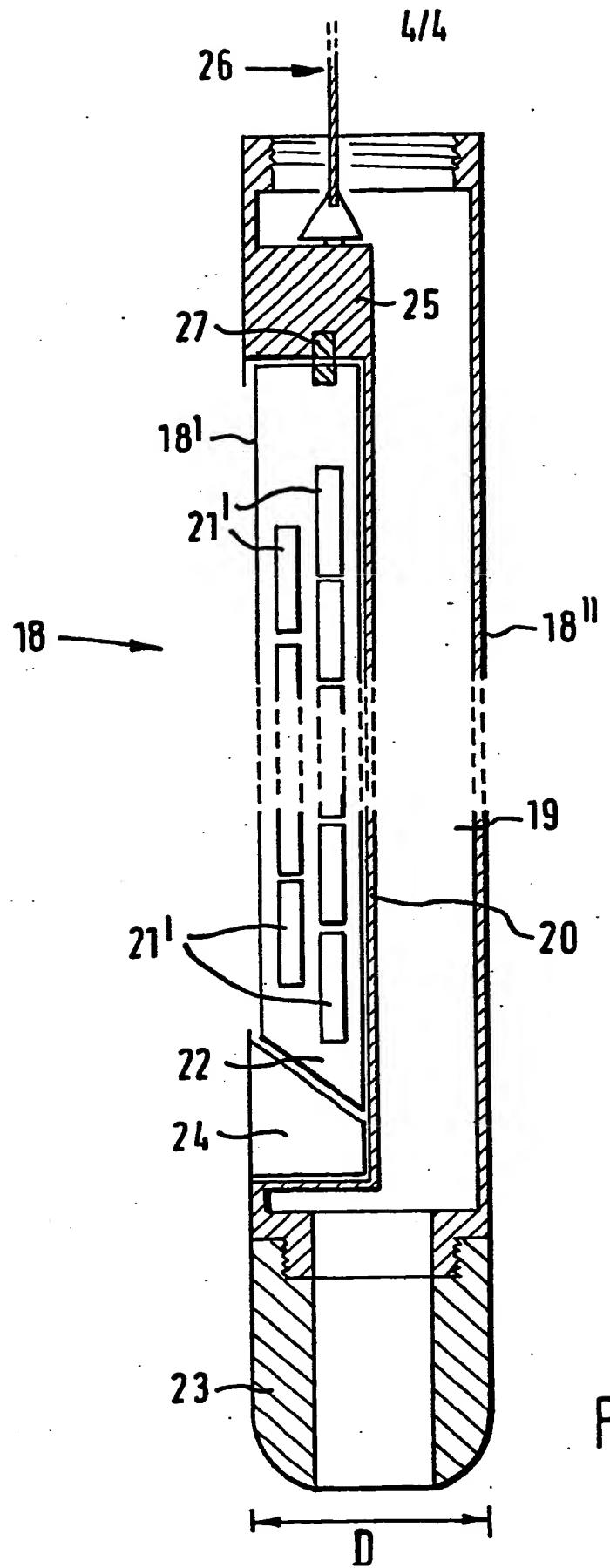


FIG. 4

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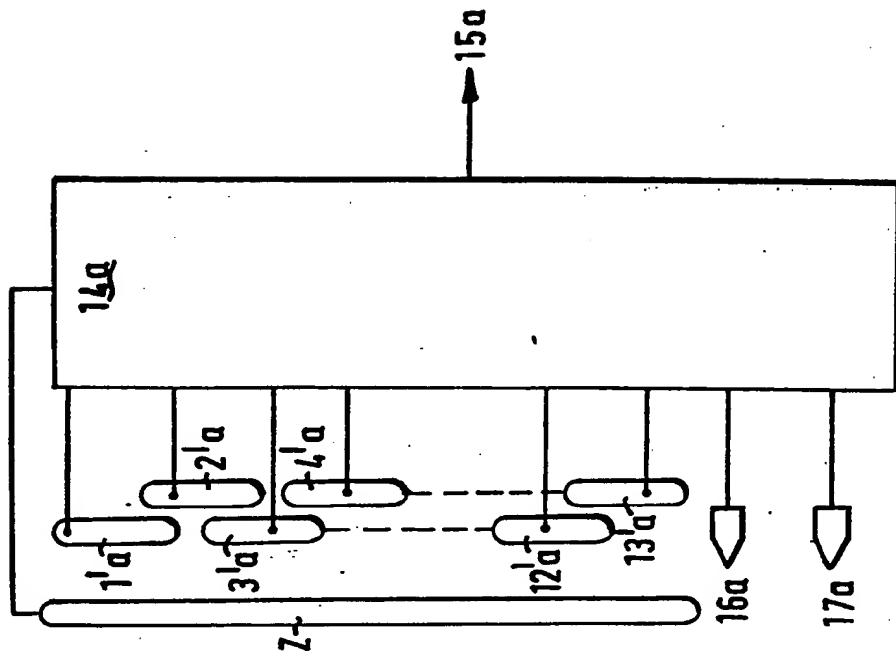


FIG. 3b

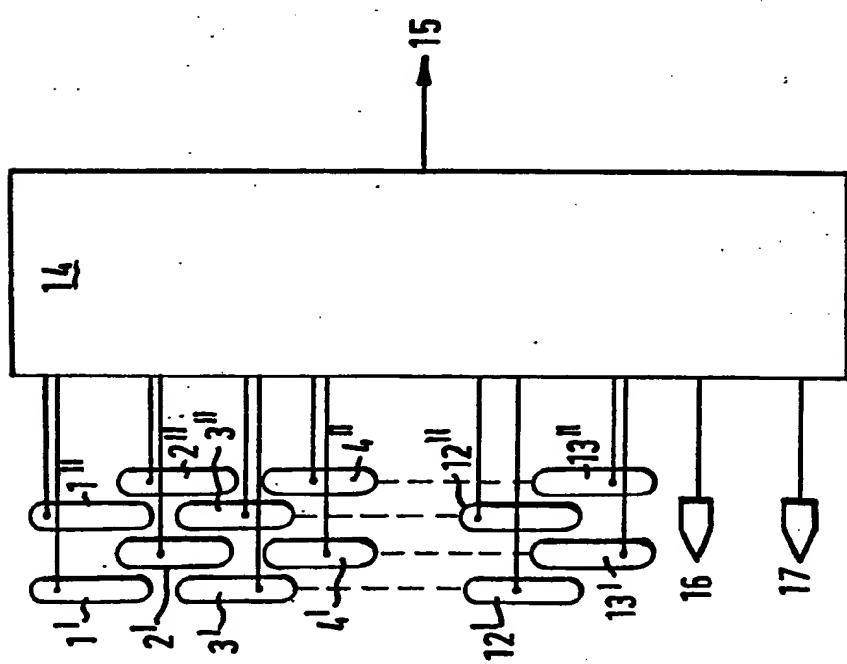
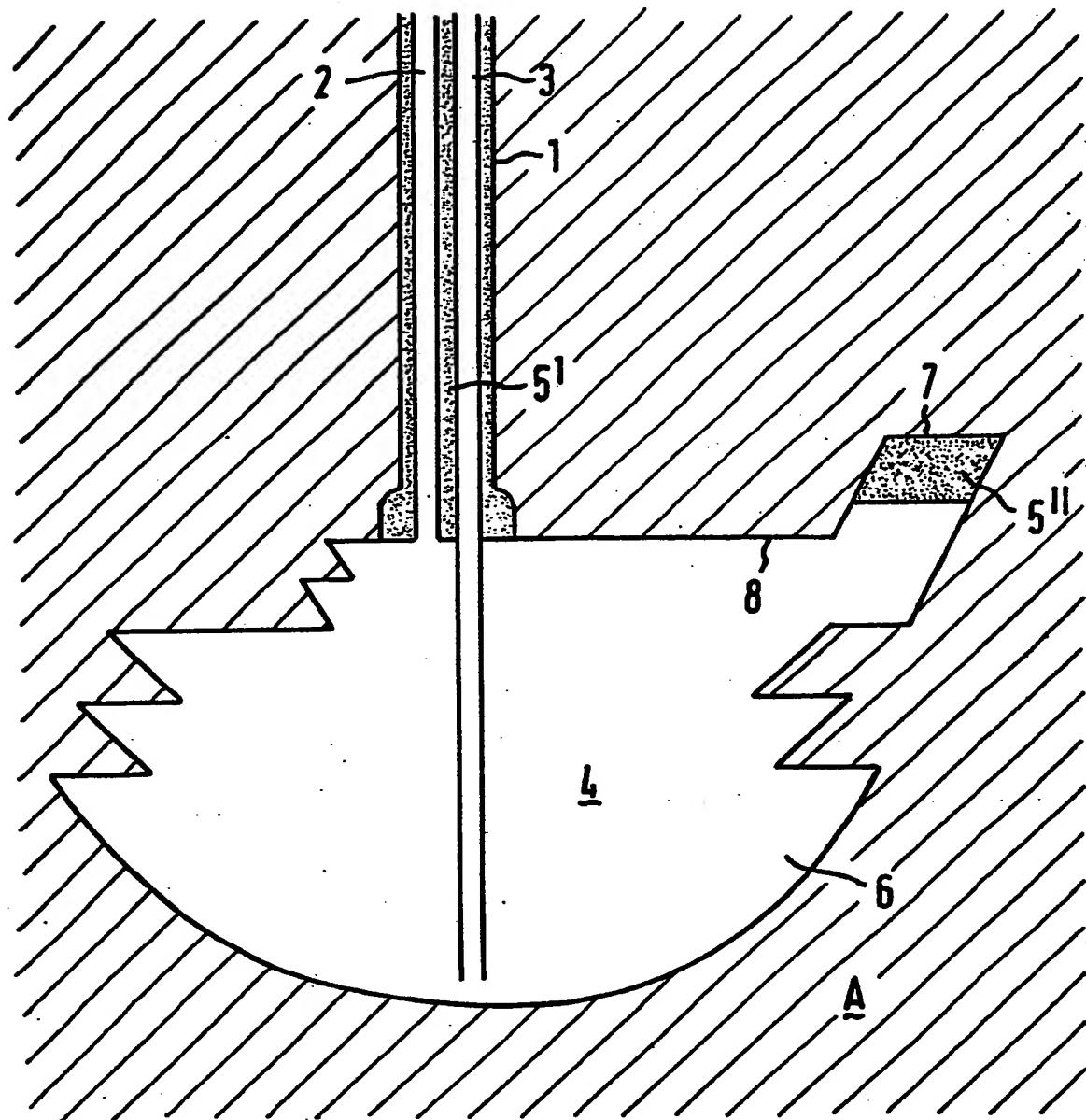


FIG. 3a

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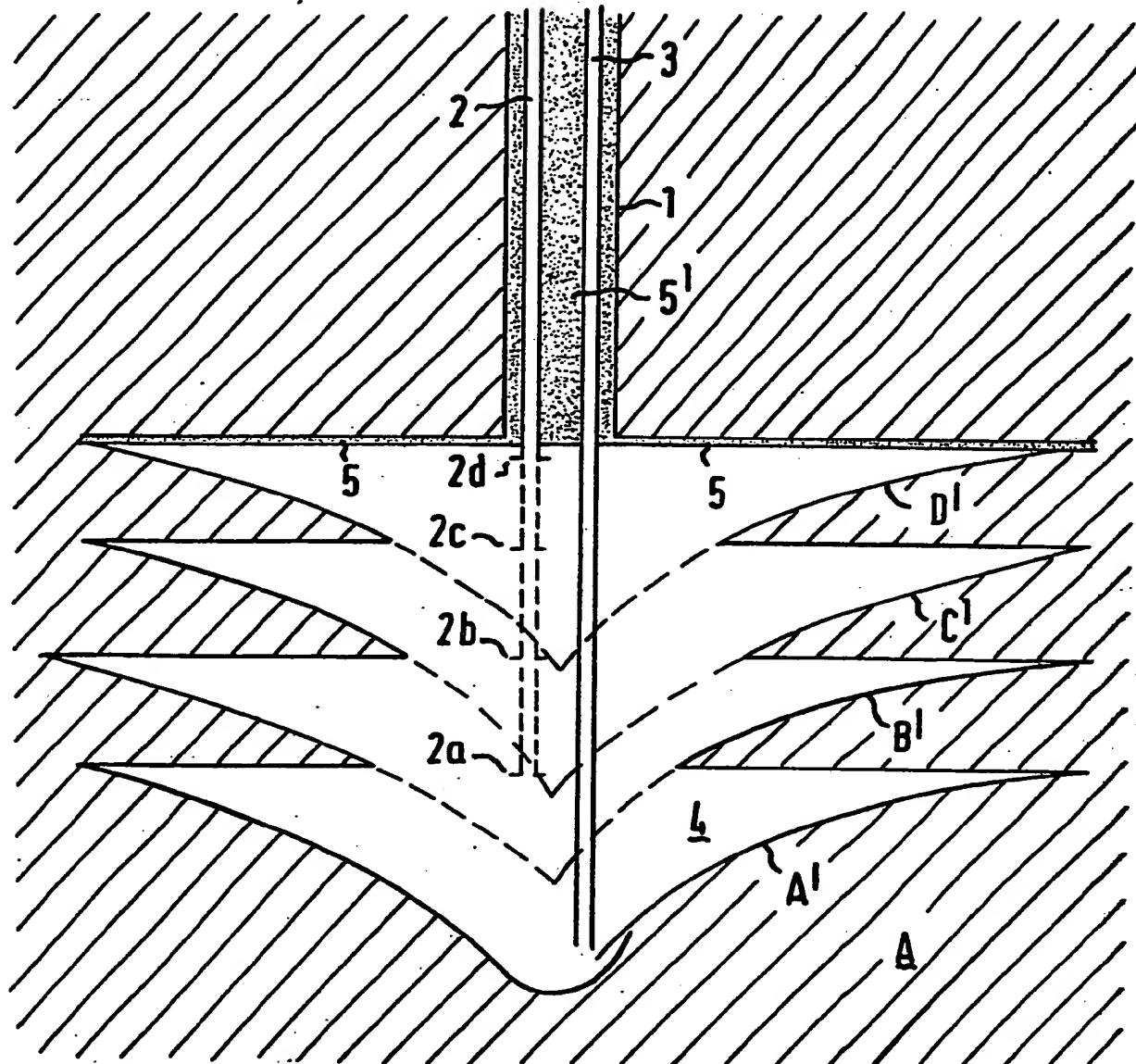


- ☒ Salt
- ◻ Brine
- Oil

FIG. 2

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- Brine
- ▨ Oil
- ▨ Salt

FIG.1

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8. The downhole tool as claimed in any one of claims 1-7,  
characterized in that a temperature sensor is present.
9. The downhole tool as claimed in any one of claims 1-8,  
characterized in that a pressure sensor is present.

C L A I M S

1. A downhole tool, to be used in a solution-mining process for detecting capacitively the position of a blanket-medium/brine interface in salt cavities, said tool being characterized by a first means which is placed at a determined distance from another 5 means, both means being adapted for capacitive measurements, the first means consisting of a plurality of individual segments, arranged one above another, and further comprising means for determining the capacitance of the said two means, the said tool further being provided with means adapted to transmit the obtained 10 information up-hole, wherein each individual segment of the first means has a height between 5 and 50 cm and a width between 1 and 5 cm.
2. The downhole tool as claimed in claim 1, characterized in that the said second means consists of a plurality of individual segments arranged one above the other, wherein each individual 15 segment has a height between 5 and 50 cm and a width between 1 and 5 cm.
3. The downhole tool as claimed in claim 1, characterized in that the said second means is the wall of a tubing, on which the tool is installed.
4. The downhole tool as claimed in any one of claims 1-3, 20 characterized by a measuring section having a length of about 2 metres.
5. The downhole tool as claimed in any one of claim 1-4, characterized in that 13 individual segments are present.
6. The downhole tool as claimed in any one of claims 1-5, 25 characterized in that individual segments with overlapping range are present.
7. The downhole tool as claimed in any one of claims 1-6, characterized in that the said plurality of individual segments and the said means for determining the capacitances are built into 30 an epoxy-glass reinforced module.

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Curved segments are for example possible in order to match the circular shape of the tubing.

It will be clear that the downhole tool has to operate in a hostile environment (saline water, high pressure, elevated  
5 temperatures, etc.).

Thus, any suitable material above to satisfy such requirements should be used. Various modifications of the invention will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are  
10 intended to fall within the scope of the appended claims.